Micriμm

Empowering Embedded Systems

μC/OS-II

μC/Probe

and the

NXP LPC2478 Processor

(Using the Embedded Artists LPC2478 OEM Evaluation Board)

Application Note

AN-1478

www.Micrium.com

About Micriμm

Micriμm provides high-quality embedded software components in the industry by way of engineer-friendly source code, unsurpassed documentation, and customer support. The company's world-renowned real-time operating system, the Micriμm **μC/OS-II**, features the highest-quality source code available for today's embedded market. Micriμm delivers to the embedded marketplace a full portfolio of embedded software components that complement **μC/OS-II**. A TCP/IP stack, USB stack, CAN stack, File System (FS), Graphical User Interface (GUI), as well as many other high quality embedded components. Micriμm's products consistently shorten time-to-market throughout all product development cycles. For additional information on Micriμm, please visit www.micrium.com.

About μC/OS-II

Thank you for your interest in **μC/OS-II**. **μC/OS-II** is a preemptive, real-time, multitasking kernel. **μC/OS-II** has been ported to over 45 different CPU architectures and now, has been ported to the Embedded Artists LPC2478 OEM evaluation board which includes the ARM-based NXP LPC2478 processor.

μC/OS-II is small yet provides all the services you would expect from an RTOS: task management, time and timer management, semaphore and mutex, message mailboxes and queues, event flags an much more.

You will find that **μC/OS-II** delivers on all your expectations and you will be pleased by its ease of use.

Licensing

μC/OS-II is provided in source form for **FREE** evaluation, for educational use or for peaceful research. If you plan on using **μC/OS-II** in a commercial product you need to contact Micriμm to properly license its use in your product. We provide ALL the source code with this application note for your convenience and to help you experience **μC/OS-II**. The fact that the source is provided **DOES NOT** mean that you can use it without paying a licensing fee. Please help us continue to provide the Embedded community with the finest software available. Your honesty is greatly appreciated.

About μC/Probe

μC/Probe is a Windows application that allows a user to display and change the value (at run-time) of virtually any variable or memory location on a connected embedded target. The user simply populates **μC/Probe**'s graphical environment with gauges, tables, graphs, and other components, and associates each of these with a variable or memory location. Once the application is loaded onto the target, the user can begin **μC/Probe**'s data collection, which will update the screen with variable values fetched from the target.

μC/Probe retrieves the values of global variables from a connected embedded target and displays the values in an engineer-friendly format. The supported data-types are: booleans, integers, floats and ASCII strings.

μC/Probe can have any number of 'data screens' where these variables are displayed. This allows to logically grouping different 'views' into a product.

Currently, there are two different trial version of **μC/Probe** :

- The Full-Featured Trial Package (30-Day Evaluation Period)
- Untimed Trial Package (15-Symbol Maximum)

Both versions can be downloaded on the Micriμm website :

http://www.micrium.com/products/probe/trialprobe.html

Manual Versions

If you find any errors in this document, please inform us and we will make the appropriate corrections for future releases.

Version	Date	By	Description
V.1.00	2008/08/11	FT	Initial version.

Software Versions

This document may or may not have been downloaded as part of an executable file, *Micrium-NXP-uCOS-II–LPC2478-EA.exe*, containing the code and projects described here. If so, then the versions of the Micriμm software modules in the table below would be included. In either case, the software port described in this document uses the module versions in the table below

Module	Version	Comment
μC/OS-II	V2.86	ARM Port V1.84
μC/OS-Probe	V2.00	

See Also

In addition to the **μC/OS-II** project accompanying this application note, a pre-compiled **μC/OS-II** and **μC/GUI** example can be found on the NXP LPC24xx page on the Micriμm website.

Document Conventions

Numbers and Number Bases

- Hexadecimal numbers are preceded by the "0x" prefix and displayed in a monospaced font. Example: `0xFF886633`.
- Binary numbers are followed by the suffix "b"; for longer numbers, groups of four digits are separated with a space. These are also displayed in a monospaced font. Example: `0101 1010 0011 1100b`.
- Other numbers in the document are decimal. These are displayed in the proportional font prevailing where the number is used.

Typographical Conventions

- Hexadecimal and binary numbers are displayed in a monospaced font.
- Code excerpts, variable names, and function names are displayed in a monospaced font. Functions names are always followed by empty parentheses (e.g., `OS_Start()`). Array names are always followed by empty square brackets (e.g., `BSP_Vector_Array[]`).
- File and directory names are always displayed in an italicized serif font. Example: */Micrium/Sofware/uCOS-II/Source/*.
- A bold style may be layered on any of the preceding conventions—or in ordinary text—to more strongly emphasize a particular detail.
- Any other text is displayed in a sans-serif font.

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1. Introduction

This document, ***AN-1478***, explains example code for using **μC/OS-II** and **μC/OS-Probe** with the Embedded Artists LPC2478 OEM Evaluation Board, as shown in Figure 1-1, which employs NXP's ARM7TDMI-based LPC2478 microcontroller. The processor includes 512 kB on-chip flash memory and 64-kB SRAM in addition to dedicated SRAM for the EMAC and DMA peripherals. The chip includes serial interfaces such as an internal 10/100 EMAC, USB device and host (with support for an external OTG transceiver), two CAN channels, a SPI controller, two SSP controllers, four UARTs, and several I^2C and I^2S interfaces . Additionally, the chip has a SD/MMC card interface, many general purpose I/O pins, and a 10-bit A/D converter.

The LPC2478 OEM daughterboard includes the processor, a National DP83848 PHY, and external memories. The baseboard on which this is situated provides the user peripherals, including five user push buttons (one of which is attached to an interrupt line), one potentiometer, on 3-axis accelerometer, a 5-key joystick and four LEDs. One RS-232 port (for the processor's UART2), a USB port used for a serial bridge (for UART0), one CAN port, one USB device port, one USB host port, a SD/MMC card holder, and an Ethernet port provide for external communication. The board includes a standard 20-pin JTAG connector for debugging and programming.

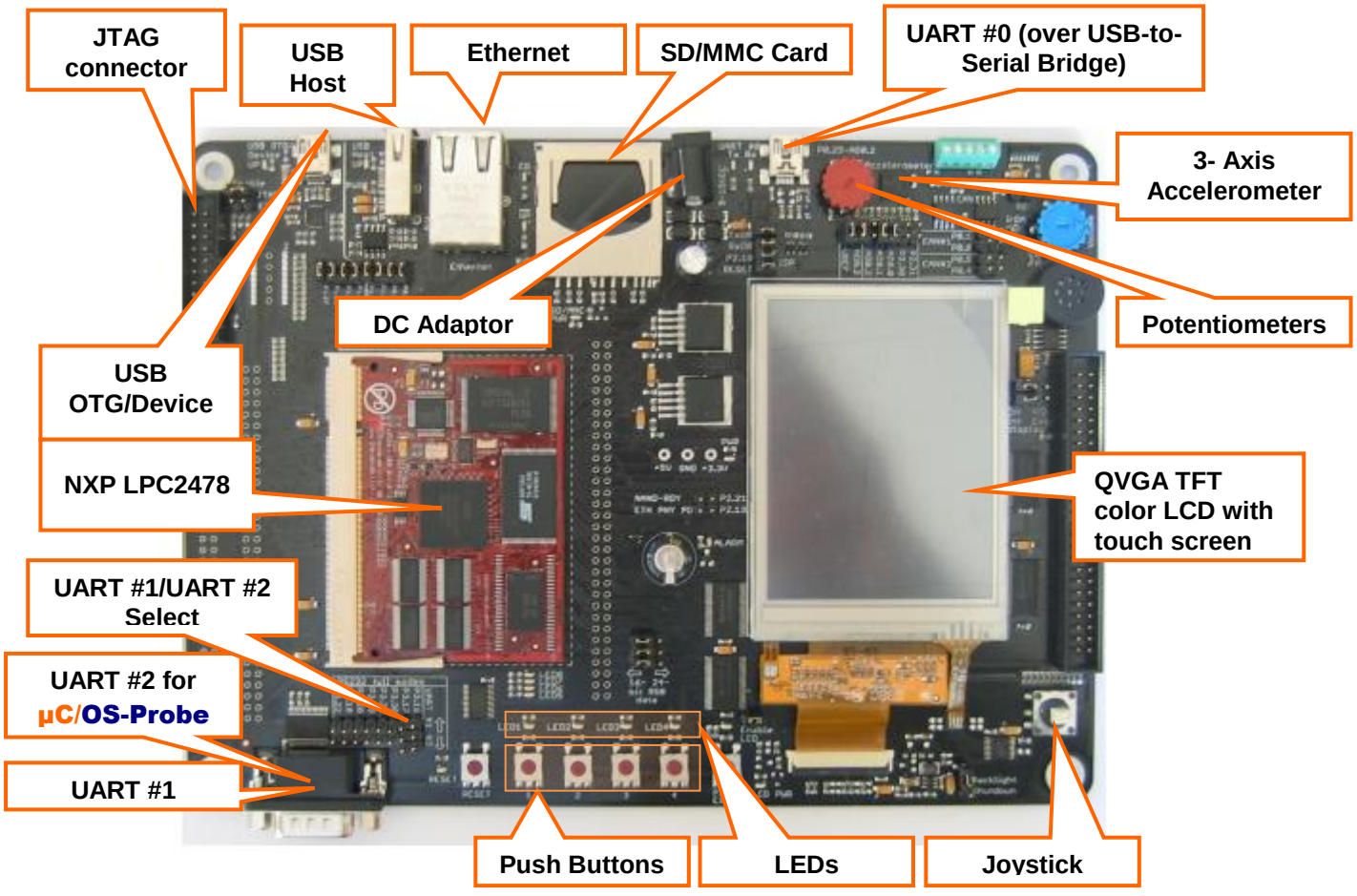


Figure 1-1. Embedded Artists LPC2478 OEM Evaluation Board

If this appnote was downloaded in a packaged executable zip file, then it should have been found in the directory */Micrium/Appnotes/AN1xxx-RTOS/AN1478-uCOS-II-NXP-LPC2478* and the code files referred to herein are located in the directory structure displayed in Section 2.02; these files are described in Section 3.

The executable zip also includes example workspaces for **μC/Probe**. **μC/Probe** is a Windows program which retrieves the value of variables form a connected embedded target and displays the values in an engineer-friendly format. It interfaces with the NXP LPC2378 via RS-232C. For more information, including instructions for downloading a trial and the demo version of the program, please refer to Section 6.

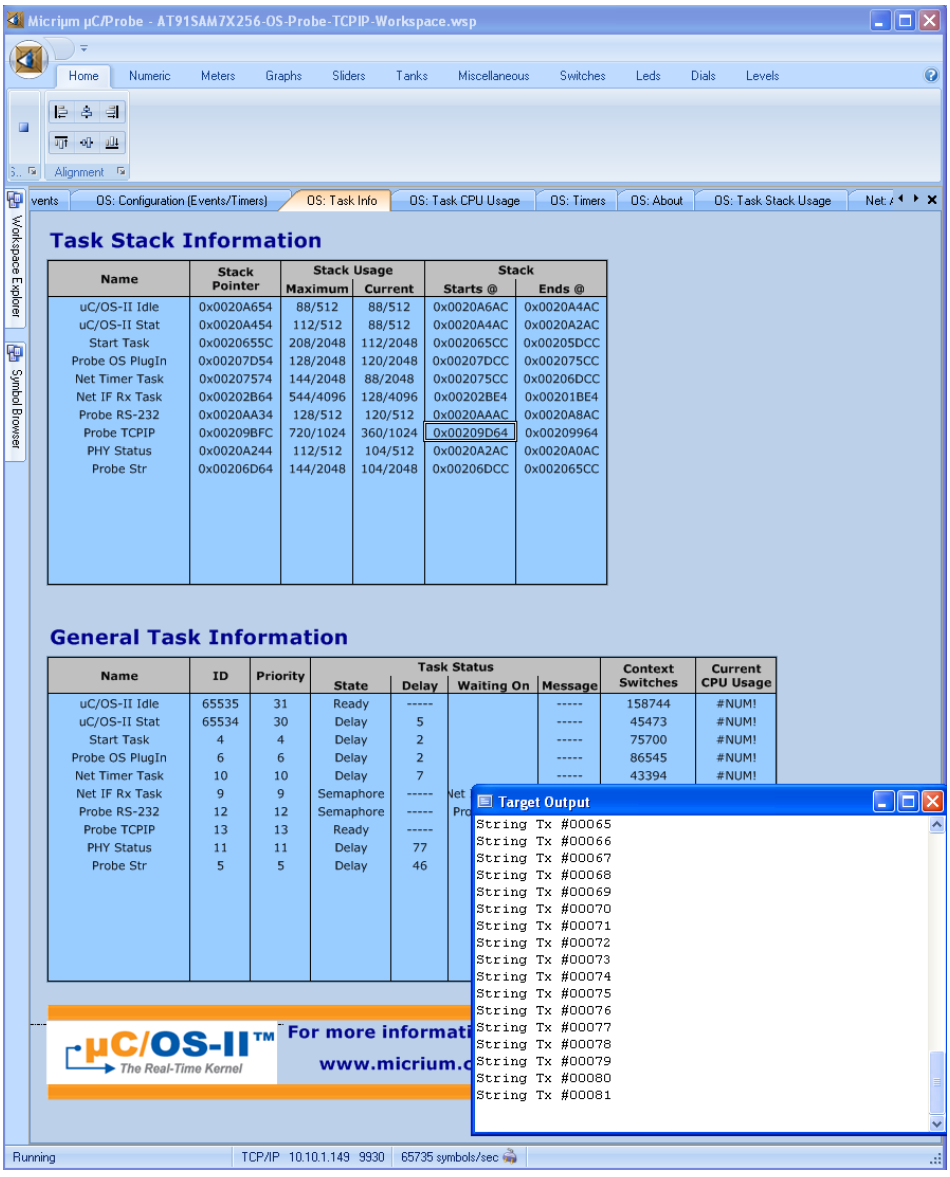


Figure 1-2. μC/Probe (with Target Output Window)

2. Getting Started

The following sections step through the prerequisites for using the demonstration application described in this document, ***AN-1478***. First, the setup of the hardware will be outlined. Second, the use and setup of the IAR Embedded Workbench project. Thirdly, the steps to build the projects and load the application onto the board through the JTAG will be described. Lastly, instructions will be provided for using the example application.

2.01 Setting up the Hardware

If **μC/OS-Probe** is being used then connect the RS-232 cable to the port labeled "UART #2 for **μC/OS-Probe**" in Figure 1-1. The project can also be configured to use UART0—which uses a USB port via a USB-to-serial bridge (described below). See Section 2.05 for details.

The board can be powered either by an external DC adapter or through the USB port used for the USB-to-serial bridge (labeled "UART0 (over USB-to-Serial Bridge in Figure 1-1. When first connecting the USB cable between the evaluation board and your computer, you will be prompted to install the FTDI driver (see the board manual for details). Once you have this driver installed, your computer can use this particular USB port on the board port as if it were a COM port. Included in this is the ability to program the LPC2478 through the UART0 (ISP). If you want to use UART0 (or use power from this USB port), but do not want to use ISP, you will need to open the jumpers "RST" and "P2.10"

2.02 Opening and Viewing the Project

If this file were downloaded as part of an executable zip file (which should have been named *Micrium-NXP-uCOS-II-LPC2478-EA.exe*), then the code files referred to herein are located in the directory structure shown in Figure 2-1.

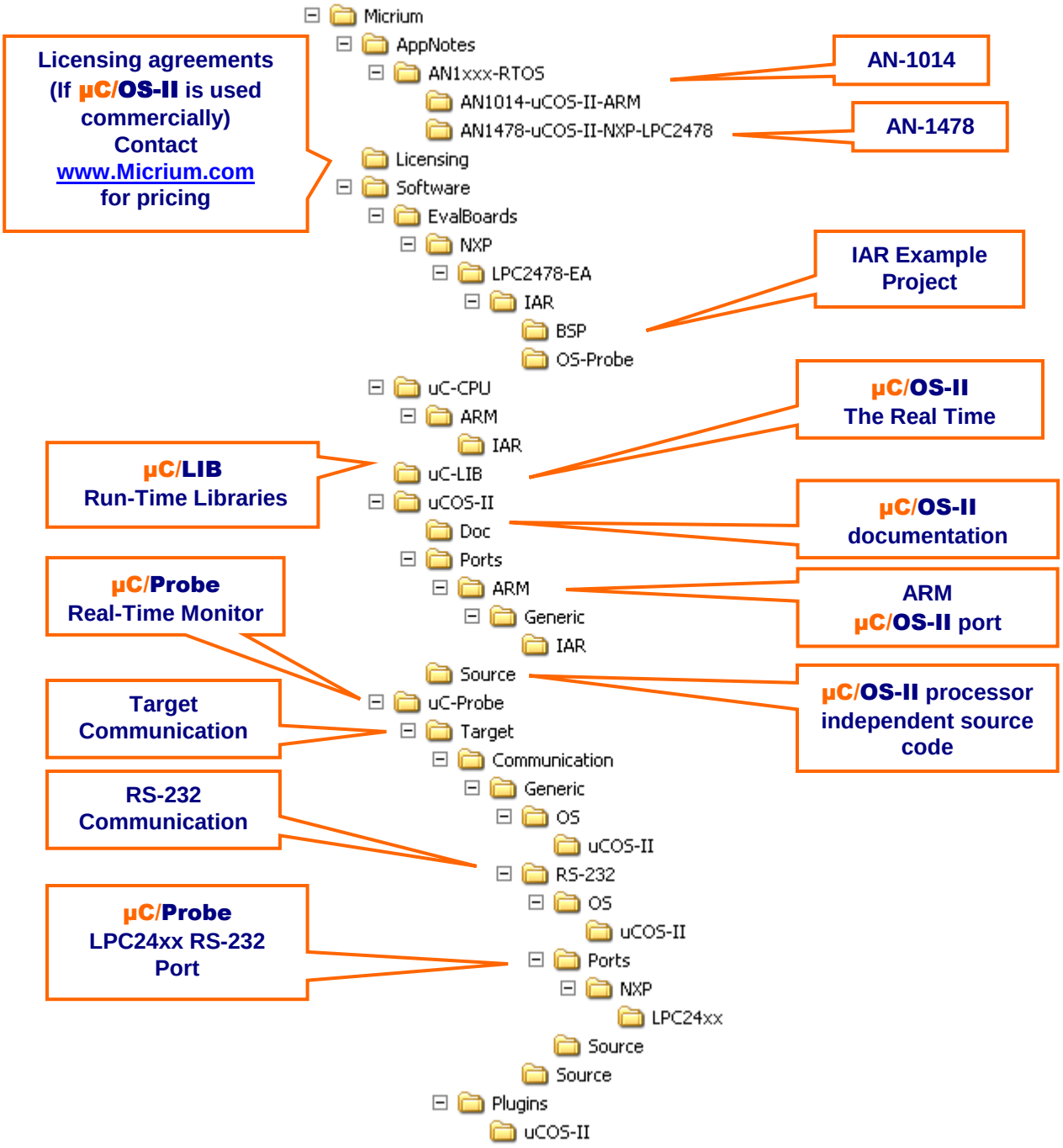


Figure 2-1. Directory Structure

2.03 Using the IAR Project

An IAR project file named ***LPC2478-EA-OS-Probe-v5-2.eww*** is located in the directory (marked "IAR Example Project" in Figure 2-2)

/Micrium/Software/EvalBoards/NXP/LPC2478-EA/IAR/OS-Probe

To view this example project, start an instance of IAR EWARM, and open the workspace file *LPC2478-EA-OS-Probe-V5-2.eww*. To do this, select the "Open" menu command under the "File" menu, select the "Workspace…" submenu command and select the workspace file after navigating to the project directory. The project tree shown in Figure 2-3 should appear. (In addition, the workspace should be openable by double-clicking on the file itself in a Windows Explorer window.)

The example project, ***LPC2478-EA-OS-Probe-v5-2.eww***, is intended for EWARM v5.2x.

2.03.01 μC/OS-II Kernel Awareness

When running the IAR C-Spy debugger, the **μC/OS-II** Kernel Awareness Plug-In can be used to provide useful information about the status of **μC/OS-II** objects and tasks. If the **μC/OS-II** Kernel Awareness Plug-In is currently enabled, then a "μC/OS-II" menu should be displayed while debugging. Otherwise, the plug-in can be enabled. Stop the debugger (if it is currently active) and select the "Options" menu item from the "Project" menu. Select the "Debugger" entry in the list box and then select the "Plugins" tab pane. Find the **μC/OS-II** entry in the list and select the check box beside the entry, as shown in Figure 2-2.

When the code is reloaded onto the evaluation board, the "μC/OS-II" menu should appear. Options are included to display lists of kernel objects such as semaphores, queues, and mailboxes, including for each entry the state of the object. Additionally, a list of the current tasks may be displayed, including for each task pertinent information such as used stack space, task status, and task priority, in addition to showing the actively executing task. An example task list for this project is shown in Figure 2-7.

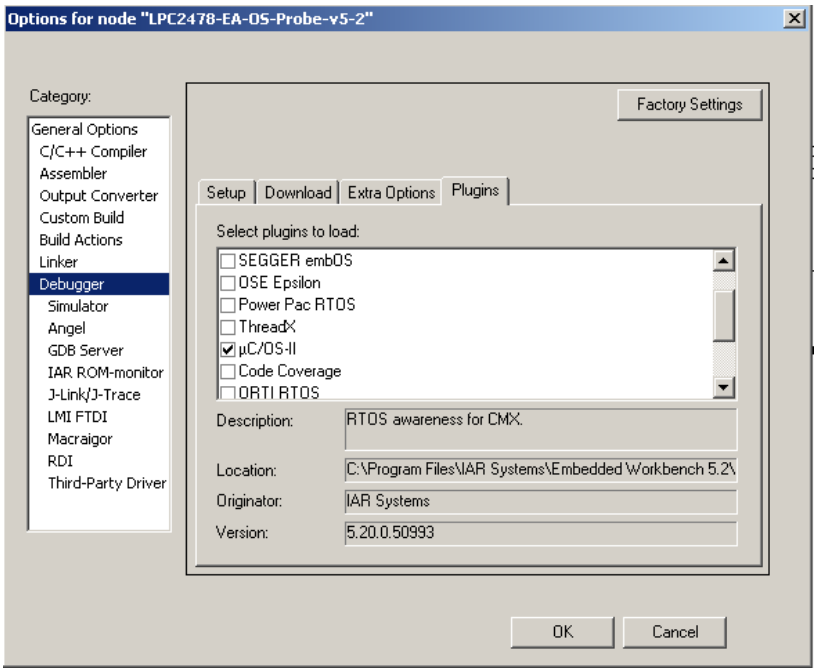


Figure 2-2. Enabling the μC/OS-II Kernel Awareness Plug-In

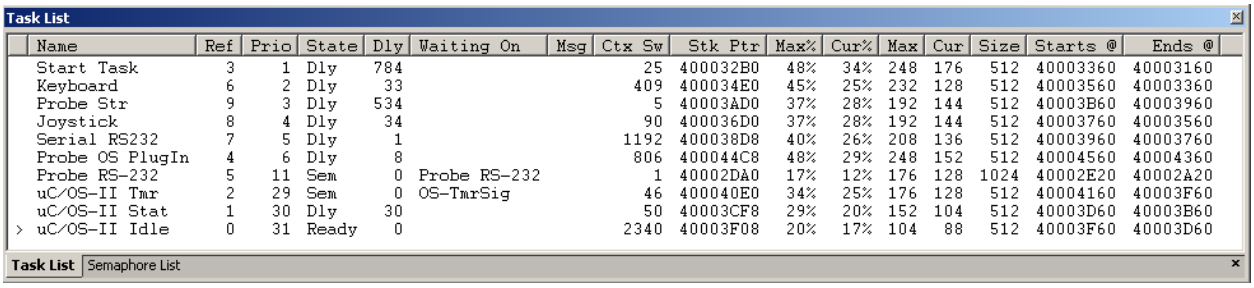


Figure 2-3. μC/OS-II Task List for *LPC2478-EA-OS-Probe-V5-2.ewp*

2.05 Example Application

Once the program is loaded onto the target, the LEDs will begin turning on, one-by-one. The LEDs will then be all turned off. If any of the push buttons have been pressed since this last occurred, then the corresponding LEDs (the LEDs directly above those push buttons) will blink rapidly 20 times.

The potentiometer controls the delay between the lighting of the LEDs in the initial phase; turning the potentiometer counter-clockwise will decrease the delay. Similarly, the left-hand potentiometer controls the rate at which the LEDs blink which correspond to the pressed push buttons; turning the potentiometer counter-clockwise will decrease the delay.

Also, Text will be output to the RS-232 port labeled as “UART #0 (over USB-to-Serial Bridge)” (at 115200 baud) giving the state of the system as shown in Figure 2-3. The joystick (pressing to the left or to the right) can be used to change the output to a new item.

To communicate with the board through RS-232, connect a serial cable between the evaluation board serial port and your PC and open a HyperTerminal or any Terminal program window. Configure the RS-232 interface with the following settings:

- Bits per Second: 115200
- Data bits 8
- Parity: None
- Stops bits: 1
- Flow Control: None

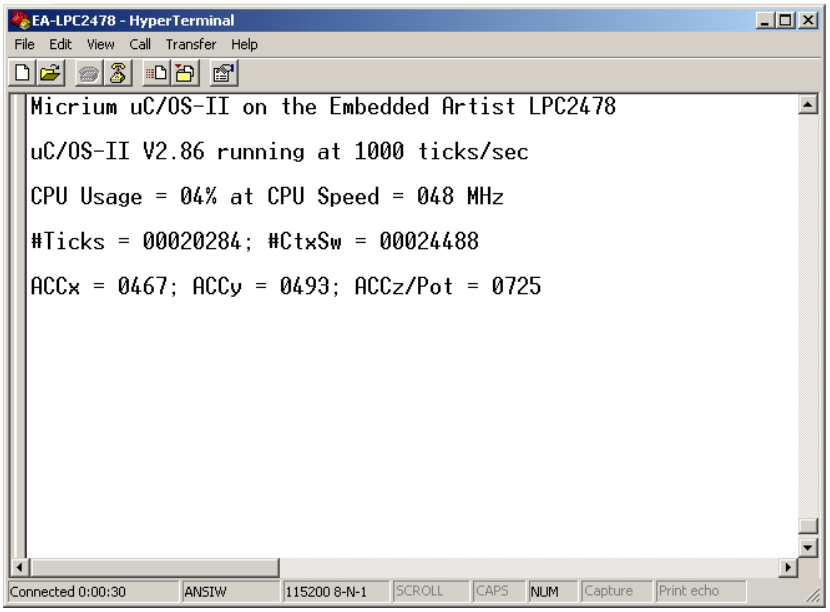


Figure 2-3. Example Application serial output

The RS-232 port labeled as “UART #2” is used for **μC/Probe** (at 115200 baud), which allows you to view (in real-time) the value of static / global variables in the target system.

2.05.0 Additional Information

Including the **μC/OS-II** system tasks, the example application includes ten tasks, as listed in Table 2-1. The board hardware used in the application is diagrammed in Figure 2-4.

Task Name	Priority	Function
`App_TaskStart()` "Start Task"	1	Starts **μC/OS-Probe**; reads ADCs, blinks LEDs.
`App_TaskKbd()` "Keyboard"	2	Reads status of push buttons; passes IDs of pressed buttons to `App_TaskStart()` in a queue.
`App_TaskProbeStr()` "Probe Str"	3	Outputs strings to the Windows **μC/Probe** program
`App_TaskJoy()` "Joystick"	4	Increment/decrement the state of the system screens base on the joystick status.
`App_TaskSer ()` "Serial RS232	5	Outputs information through the RS-232 port
"Probe OS PlugIn"	6	Updates CPU usage for **μC/Probe**.
"Probe RS-232"	11	Parses packets from **μC/Probe**.
"uC/OS-II Tmr"	29	Manages **μC/OS-II** timers
"uC/OS-II Stat"	30	Collect stack usage statistics
"uC/OS-II Idle"	31	Executes when no other task is executing.

Table 2-1. Example Application Tasks

The project is configured so that code is loaded into Flash and the stacks and data are loaded into RAM, as shown in Table 2-2.

Memory Range	Size	Segment(s)
`0x00000000- 0x0007FFFF`	512 kB	Code (in Flash)
`0x40000000- 0x4000FFFF`	64 kB	Stacks and data (in RAM)

Table 2-2. Example Application Tasks

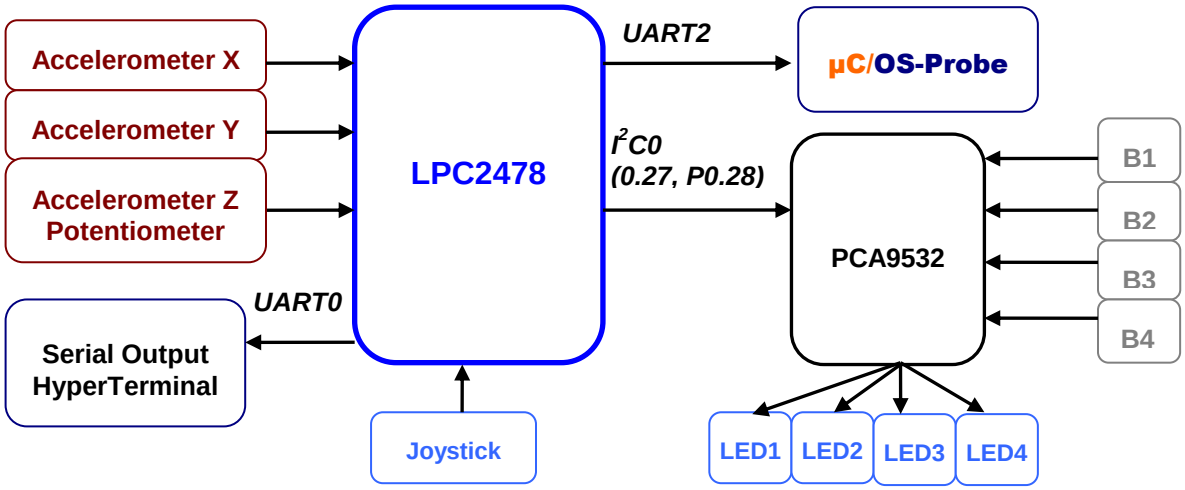


Figure 2-4. Example Application Hardware Use

3. Directories and Files

Application Notes

\Micrium\AppNotes\AN1xxx-RTOS\AN1014-uCOS-II-ARM

This directory contains ***AN-1014.pdf***, the application note describing the ARM port for **μC/OS-II**, and ***AN-1014-PPT.pdf***, a supplement to *AN-1014.pdf*.

\Micrium\AppNotes\AN1xxx-RTOS\AN1478-uCOS-II-NXP-LPC2478

This directory contains this application note, ***AN-1478.pdf***.

Licensing Information

\Micrium\Licensing

Licensing agreements are located in this directory. Any source code accompanying this appnote is provided for evaluation purposes only. If you choose to use **μC/OS-II** in a commercial product, you must contact Micriμm regarding the necessary licensing.

μC/OS-II Files

\Micrium\Software\uCOS-II\Doc

This directory contains documentation for **μC/OS-II**.

\Micrium\Software\uCOS-II\Ports\ARM\Generic\IAR

This directory contains the standard processor-specific files for the generic **μC/OS-II** ARM port assuming the IAR toolchain and the ARM/Keil "RealView Microprocessor Development Kit" toolchain. These files could easily be modified to work with other toolchains (i.e., compiler/assembler/linker/locator/debugger); however, the modified files should be placed into a different directory. The following files are in this directory:

- *os_cpu.h*
- *os_cpu_a.asm*
- *os_cpu_c.c*
- *os_dcc.c*
- *os_dbg.c*

With this port, **μC/OS-II** can be used in either ARM or Thumb mode. Thumb mode, which drastically reduces the size of the code, was used in this example, but compiler settings may be switched (as discussed in Section 2.30) to generate ARM-mode code without needing to change either the port or the application code. The ARM/Thumb port is described in application note *AN-1014* which is available from the Micrium web site.

\Micrium\Software\uCOS-II\Source

This directory contains the processor-independent source code for **μC/OS-II**.

μC/Probe Files

\Micrium\Software\uC-Probe\Communication\Generic

This directory contains the **μC/Probe** generic communication module, the target-side code responsible for responding to requests from the **μC/Probe** Windows application (including requests over RS-232).

\Micrium\Software\uC-Probe\Communication\Generic\Source

This directory contains ***probe_com.c*** and ***probe_com.h***, the source code for the generic communication module.

\Micrium\Software\uC-Probe\Communication\Generic\OS\uCOS-II

This directory contains ***probe_com_os.c***, which is the **μC/OS-II** port for the **μC/Probe** generic communication module.

\Micrium\Software\uC-Probe\Communication\Generic\Source\RS-232

This directory contains the RS-232 specific code for **μC/Probe** generic communication module, the target-side code responsible for responding to requests from the **μC/Probe** Windows application over RS-232

\Micrium\Software\uC-Probe\Communication\Generic\Source\RS-232\Source

This directory contains ***probe_rs232.c*** and ***probe_rs232.h***, the source code for the generic communication module RS-232 code.

\Micrium\Software\uC-Probe\Communication\Generic\Source\RS-232\Ports\NXP\LPC24xx

This directory contains ***probe_rs232c.c*** and ***probe_rs232c.h***, the NXP LPC24xx port for the RS-232 communications.

\Micrium\Software\uC-Probe\Communication\Generic\Source\RS-232\OS\uCOS-II

This directory contains ***probe_rs232_os.c***, which is the **μC/OS-II** port for the **μC/Probe** RS-232 communication module.

μC/CPU Files

\Micrium\Software\uC-CPU

This directory contains ***cpu_def.h***, which declares `#define` constants for CPU alignment, endianness, and other generic CPU properties.

\Micrium\Software\uC-CPU\ARM\IAR

This directory contains ***cpu.h*** and ***cpu_a.s***. *cpu.h* defines the Micriμm portable data types for 8-, 16-, and 32-bit signed and unsigned integers (such as `CPU_INT16U`, a 16-bit unsigned integer). These allow code to be independent of processor and compiler word size definitions. *cpu_a.s* contains generic assembly code for ARM7 and ARM9 processors which is used to enable and disable interrupts within the operating system. This code is called from C with `OS_ENTER_CRITICAL()` and `OS_EXIT_CRITICAL()`.

μC/LIB Files

\Micrium\Software\uC-LIB

This directory contains ***lib_def.h***, which provides `#defines` for useful constants (like `DEF_TRUE` and `DEF_DISABLED`) and macros.

\Micrium\Software\uC-LIB\Doc

This directory contains the documentation for **μC/LIB**.

Application Code

\Micrium\Software\EvalBoards\NXP\LPC2478-EA\IAR\OS-Probe

This directory contains the source code the example application:

- ***app.c*** contains the test code for the example application including calls to the functions that start multitasking within **μC/OS-II**, register tasks with the kernel, and update the user interface (the LEDs and the push buttons). ***app_cfg.h*** is a configuration file specifying stack sizes and priorities for all user tasks and `#define`s for important global application constants.
- ***includes.h*** is the master include file used by the application.
- ***os_cfg.h*** is the **μC/OS-II** configuration file.
- ***LPC2478-EA-OS-Probe-v5-2.**** are the IAR Embedded Workbench project files.
- ***LPC2478-EA-OS-Probe-Workspace.wsp*** is an example **μC/Probe** workspace.

\Micrium\Software\EvalBoards\NXP\LPC2478-EA\IAR\BSP

This directory contains the Board Support Package for the Embedded Artists LPC2478 OEM evaluation board:

- ***bsp.c*** contains the board support package functions which initialize critical processor functions (e.g., the PLL) and provide support for peripherals such as the push button and potentiometer. ***bsp.h*** contains prototypes for functions that may be called by the user.
- ***bsp_i2c.c*** contains a port for the NXP LPC2478 I^2C interface, aimed specifically at supporting the PCA9532 LED dimmer which controls the LEDs and push buttons on the board.
- ***cstartup.s*** performs critical processor initialization (such as the initialization of task stacks), readying the platform to enter `main()`.
- ***LPC2478_Flash.icf*** is the IAR linker files which contain information about the placement of data and code segments in the processor's memory map.
- ***LPC2478_Flash.mac*** contains instructions that are executed prior to loading code onto the processor.

4. Application Code

The example application described in this appnote, *AN-1478*, is a simple demonstration of **μC/OS-II** and **μC/OS-Probe** for the NXP LPC2478 processor on the Embedded Artists LPC2478 OEM evaluation board.

4.01 *app.c*

Five functions of interest are located in *app.c*:

1. **`main()`** is the entry point for the application, as it is with most C programs. This function initializes the operating system, creates the primary application task, `App_TaskStart()`, begins multitasking, and exits.

2. **`App_TaskStart()`**, after creating the user interface tasks, enters an infinite loop in which it blinks the LEDs (at rates determined by the potentiometers) and checks a queue to see if push buttons have been pressed (see Figure 2-14).

3. **`App_TaskKbd()`** polls the user inputs—the push buttons—and, if new input is detected, places a message in a queue for `App_TaskStart()`.

4. **`App_TaskJoy()`** monitors the state of the joystick and passes messages to `App_TaskSer()`

5. **`App_TaskSer()`**,Outputs the state of the system based on the display state passed to it by `App_TaskJoy()`.

```
int  main (void)                                                    /* Note 1 */
{
    CPU_INT08U  err;


    BSP_IntDisAll();                                                /* Note 2 */

    OSInit();                                                       /* Note 3 */

    OSTaskCreateExt((void (*)(void *)) App_TaskStart,               /* Note 4 */
                    (void           *) 0,
                    (OS_STK         *)&AppTaskStartStk[APP_CFG_TASK_START_STK_SIZE - 1],
                    (INT8U           ) APP_CFG_TASK_START_PRIO,
                    (INT16U          ) APP_CFG_TASK_START_PRIO,
                    (OS_STK         *)&AppTaskStartStk[0],
                    (INT32U          ) APP_CFG_TASK_START_STK_SIZE,
                    (void           *) 0,
                    (INT8U           )(OS_TASK_OPT_STK_CHK | OS_TASK_OPT_STK_CLR));

#if (OS_TASK_NAME_SIZE > 13)                                        /* Note 5 */
    OSTaskNameSet(APP_CFG_TASK_START_PRIO, (CPU_INT08U *)"Start Task", &err);
#endif

    OSStart();                                                      /* Note 6 */
}
```

Listing 4-1, `main()`

Listing 4-1, Note 1: As with most C applications, the code starts in `main()`.

Listing 4-1, Note 2: All interrupts are disabled to make sure the application does not get interrupted until it is fully initialized.

Listing 4-1, Note 3: `OSInit()` must be called before creating a task or any other kernel object, as must be done with all **μC/OS-II** applications.

Listing 4-1, Note 4: At least one task must be created (in this case, using `OSTaskCreateExt()` to obtain additional information about the task). In addition, **μC/OS-II** creates either one or two internal tasks in `OSInit()`. **μC/OS-II** always creates an idle task, `OS_TaskIdle()`, and will create a statistic task, `OS_TaskStat()` if you set `OS_TASK_STAT_EN` to 1 in *os_cfg.h*.

Listing 4-1, Note 5: As of V2.6x, you can now name **μC/OS-II** tasks (and other kernel objects) and display task names at run-time or with a debugger. In this case, the `App_TaskStart()` is given the name “Start Task”. Because C-Spy can work with the Kernel Awareness Plug-In available from Micriμm, task names can be displayed during debugging.

Listing 4-1, Note 6: Finally multitasking under **μC/OS-II** is started by calling `OSSTart()`. **μC/OS-II** will then begin executing `App_TaskStart()` since that is the highest-priority task created (both `OS_TaskStat()` and `OS_TaskIdle()` having lower priorities).

```
static  void  App_TaskStart (void *p_arg)
{
    CPU_INT08U   i;
    CPU_INT08U   j;
    void        *msg;
    CPU_INT08U   err;
    CPU_INT08U   led;
    CPU_INT32U   leds;
    CPU_INT32U   delay0;
    CPU_INT32U   delay1;


    (void)p_arg;
    BSP_Init();                                                 /* Note 1 */

#if (OS_TASK_STAT_EN > 0)
    OSStatInit();                                               /* Note 2 */
#endif

#if (APP_CFG_PROBE_COM_EN == DEF_ENABLED)
    App_ProbeInit();                                            /* Note 3 */
#endif

    App_EventCreate() ;                                         /* Note 4 */
    App_TaskCreate();

    BSP_Ser_Init(115200);
    BSP_LED_Off(0);

    while (DEF_TRUE) {                                          /* Note 5 */

        for (i = 1; i <= 4; i++) {                              /* Note 6 */
            BSP_LED_On(i);
            delay0 = BSP_ADC_GetStatus(BSP_ADC_POT) + 32;
            OSTimeDlyHMSM(0, 0, delay0 / 1000, delay0 % 1000);
        }

        BSP_LED_Off(0);
        delay0 = BSP_ADC_GetStatus(BSP_ADC_POT);
        OSTimeDlyHMSM(0, 0, delay0 / 1000, delay0 % 1000);

        leds = 0;
        while (1) {
            msg  = OSQAccept(AppKbdQ, &err);                    /* Note 7 */

            if (err == OS_Q_EMPTY || msg == (void *)0) {
                break;
            }

            led  = (CPU_INT32U)msg;

            if (led > 4) {
                break;
            }

            leds |= (1 << led);
        }
       if (leds == 0) {
            continue;
        }
        for (j = 0; j < 20; j++) {                                /* Note 8 */
            for (i = 1; i <= 4; i++) {
                if ((leds & (1 << i)) == (1 << i)) {
                    BSP_LED_Toggle(i);
                }
            }
            delay1 = (BSP_ADC_GetStatus(BSP_ADC_POT) >> 2) + 32;
            OSTimeDlyHMSM(0, 0, delay1 / 1000, delay1 % 1000);
        }
    }
}
```

Listing 4-2, `App_TaskStart()`

Listing 4-2, Note 1: `BSP_Init()` initializes the Board Support Package—the I/Os, tick interrupt, etc. See Section 5 for details.

Listing 4-2, Note 2: `OSStatInit()` initializes **μC/OS-II**'s statistic task. This only occurs if you enable the statistic task by setting `OS_TASK_STAT_EN` to 1 in *os_cfg.h*. The statistic task measures overall CPU usage (expressed as a percentage) and performs stack checking for all the tasks that have been created with `OSTaskCreateExt()` with the stack checking option set.

Listing 4-2, Note 3: If **μC/OS-Probe** is enabled, then the module's initialization procedure **`App_ProbeInit()`** is called. **`App_ProbeInit()`** calls `OSProbe_Init()` which initializes the **μC/Probe** plug-in for **μC/OS-II**, which maintains CPU usage statistics for each task, `ProbeCom_Init()` that initializes the **μC/Probe** generic communication module and `ProbeRS232_Init()` that initializes the RS-232 communication module. After these have been initialized, the **μC/Probe** Windows program will be able to download data from the processor. For more information, see Section 6.

Listing 4-2, Note 4: **`App_EventCreate()`** Creates all the application uC/OS-II events and **`App_TaskCreate()`** creates all the application tasks.

Listing 4-2, Note 5: Any task managed by **μC/OS-II** must either enter an infinite loop 'waiting' for some event to occur or terminate itself. This task enters an infinite loop in which it toggles the LEDs at rates determined by the potentiometer settings.

Listing 4-2, Note 6: The four LEDs are turned on, one by one, and then all of the LEDs are turned off.

Listing 4-2, Note 7: The task checks the queue `AppKbdQ` to see if any messages have been posted.

Listing 4-2, Note 8: If messages were posted (indicating that push buttons were pressed), then the LEDs corresponding to the pressed push buttons will be blinked 20 times. If no messages were posted, then the task will have continued at the beginning of the loop.

4.02 *os_cfg.h*

The file ***os_cfg.h*** is used to configure **μC/OS-II** and defines the maximum number of tasks that your application can have, which services will be enabled (semaphores, mailboxes, queues, etc.), the size of the idle and statistic task and more. In all, there are about 60 or so `#define` that you can set in this file. Each entry is commented and additional information about the purpose of each `#define` can be found in Jean Labrosse's book, ***μC/OS-II, The Real-Time Kernel, 2nd Edition***. *os_cfg.h* assumes you have **μC/OS-II** V2.83 or higher but also works with previous versions of **μC/OS-II**.

- Task sizes for the Idle (**`OS_TASK_IDLE_STK_SIZE`**), statistics **`OS_TASK_STAT_STK_SIZE`**) and timer (**`OS_TASK_TMR_STK_SIZE`**) task are set to 128 `OS_STK` elements (each is 4 bytes) and thus each task stack is 512 bytes. If you add code to the examples make sure you account for additional stack usage.

- **`OS_DEBUG_EN`** is set to 1 to provide valuable information about **μC/OS-II** objects to IAR's C-Spy through the Kernel Awareness plug-in. Setting `OS_DEBUG_EN` to 0 should some code space (though it will not save much).

- **`OS_LOWEST_PRIO`** is set to 31, allowing up to 32 total tasks.

- **OS_MAX_TASKS** determines the number of "application" tasks and is currently set to 10 allowing 9 more tasks to be added to the example code.

- **OS_TICKS_PER_SEC** is set to 1000 Hz. This value can be changed as needed and the proper tick rate will be adjusted in *bsp.c* if you change this value. You would typically set the tick rate between 10 and 1000 Hz. The higher the tick rate, the more overhead **μC/OS-II** will impose on the application. However, you will have better tick granularity with a higher tick rate.

5. Board Support Package (BSP)

The Board Support Package (BSP) provides functions to encapsulate common I/O access functions and make porting your application code easier. Essentially, these files are the interface between the application and the Embedded Artists LPC2478 OEM board. Though one file, *bsp.c*, contains some functions which are intended to be called directly by the user (all of which are prototyped in *bsp.h*), the other files serve the compiler (as with *cstartup.s79*).

5.01 IAR-Specific BSP Files

The BSP includes three files intended specifically for use with IAR tools: *LPC2478_Flash.icf*, *LPC268_Flash.mac*, *cstartup.s*. These serve to define the memory map and initialize the processor prior to loading or executing code. If the example application is to be used with other toolchains, the services provided by these files must be replicated as appropriate.

Before the processor memories can be programmed, the compiler must know where code and data should be placed. IAR requires a linker command file, such as *LPC2478_Flash.icf* that provides directives to accomplish this. The C-Spy macro files *LPC2478_Flash.mac* declares routines which will be executed prior to loading code on the processor and after a processor reset. Each of these sets the `MEMMAP` register as is appropriate for the location of the exception vectors.

In *cstartup.s* is code which will be executed prior to calling `main`. One important inclusion is the specification of the exception vector table (as required for ARM cores) and the setup of various exception stacks. After executing, this function branches to the IAR-specific `?main` function, in which the processor is further readied for entering application code.

5.03 BSP, *bsp.c* and *bsp.h*

The file *bsp.c* implements several global functions, each providing some important service, be that the initialization of processor functions for **μC/OS-II** to operate or the toggling of an LED. Several local functions are defined as well to perform some atomic duty, initializing the I/O for the LED or initialize the **μC/OS-II** tick timer. The discussion of the BSP will be limited to the discussion of the global functions that might be called from user code (and may be called from the example application).

The global functions defined in *bsp.c* (and prototyped in *bsp.h*) may be roughly divided into two categories: critical processor initialization and user interface services. Four functions constitute the former:

- **`BSP_Init()`** is called by the application code to initialize critical processor features (particularly the **μC/OS-II** tick interrupt) after multitasking has started (i.e., `OS_Start()` has been called). This function should be called before any other BSP functions are used. See Listing 5-1 for more details.
- **`BSP_IntDisAll()`** is called to disable all interrupts, thereby preventing any interrupts until the processor is ready to handle them.
- **`BSP_CPU_ClkFreq()`** returns the clock frequency in Hz.
- **`BSP_CPU_PclkFreq()`** returns the clock frequency in Hz or a peripheral clock; an ID for the peripheral clock (as defined in *bsp.h*) is accepted as the argument.

Five function provide access to user interface components:

- **`BSP_LED_Toggle()`**, **`BSP_LED_On()`** and **`BSP_LED_Off()`** will toggle, turn on, and turn off (respectively) the LED corresponding to the ID passed as the argument If an argument of 0 is provided, the appropriate action will be performed on all LEDs. Valid IDs are 1, 2, 3, and 4.
- **`BSP_PB_GetStatus()`** takes as its argument the ID of a push button and returns `DEF_TRUE` if the push button is being pressed and `DEF_FALSE` if the push button is not being pressed. Valid IDs are 1, 2, 3, and 4.
- **`BSP_ADC_GetStatus()`** takes as its argument the ID of a ADC and returns the 10-bit number that, when divided by `0x3FF`, is equal to the ratio of the input voltage divided by the reference voltage. The ID parameter can take the following values:

  `BSP_ADC_ACC_X` the AD0.0 channel, Accelerometer x-axis.
  `BSP_ADC_ACC_Y` the AD0.1 channel, Accelerometer y-axis.
  `BSP_ADC_ACC_Z` the AD0.2 channel, Accelerometer z-axis.
  `BSP_ADC_POT` the AD0.2 channel, Potentiometer.

- **`BSP_Joy_GetPos()`** return the position of the Joystick . There are 6 different values that this function can return:

  `BSP_JOY_NONE` If the Joystick is not being pressed.
  `BSP_JOY_UP` If the Joystick is toggled up.
  `BSP_JOY_DOWN` If the Joystick is toggled down.
  `BSP_JOY_RIGHT` If the Joystick is toggled right.
  `BSP_JOY_LEFT` If the Joystick is toggled left.
  `BSP_JOY_PUSH` If the Joystick is being pressed.

- **BSP_JOY_GetStatus()** return DEF_TRUE if the Joystick is being pressed at a given position. The **joy_pos** argument can take 6 different values:

  BSP_JOY_NONE If the Joystick is not being pressed.
  BSP_JOY_UP If the Joystick is toggled up.
  BSP_JOY_DOWN If the Joystick is toggled down.
  BSP_JOY_RIGHT If the Joystick is toggled right.
  BSP_JOY_LEFT If the Joystick is toggled left.
  BSP_JOY_PUSH If the Joystick is being pressed.

Six function provide access to serial port:

- **BSP_Ser_Init()** initializes either UART0, UART1 or UART2 for serial communication.
- **BSP_Ser_WrByte()** and **BSP_Ser_WrStr()** write a byte (such as a character) or string to either UART0, UART1 or UART2.
- **BSP_Ser_RdByte()** and **BSP_Ser_RdStr()** read a byte (such as a character) or string from either UART0, UART1 or UART2.
- **BSP_Ser_Printf()** can be called like printf() to provide formatted output on either UART0, UART1 or UART2.

5.04 BSP, *bsp_i2c.c*

This file includes a port for the NXP LPC2478 I2C interface targeted at supporting the PCA9532.

5.05 Processor Initialization Function

```
void  BSP_Init (void)
{
    BSP_PLL_Init();                                          /* Note 1  */
    BSP_RTC_Init();                                          /* Note 2  */
    BSP_MAM_Init();                                          /* Note 3  */
    BSP_GPIO_Init();                                         /* Note 4  */
    BSP_Joy_Init();                                          /* Note 5  */
    BSP_ADC_Init();                                          /* Note 6  */
    BSP_VIC_Init();                                          /* Note 7  */
    BSP_I2C_Init();                                          /* Note 8  */
    BSP_Tmr_TickInit();                                      /* Note 9 */
}
```

Listing 5-1, BSP_Init()

Listing 5-1, Note 1: The PLL is setup to generate a 72 MHz CPU clock. All peripheral clocks are set to half the CPU clock.

Listing 5-1, Note 2: The Real-Time clock (RTC) is setup.

Listing 5-1, Note 3: The Memory Acceleration Module (MAM) is setup.

Listing 5-1, Note 4: The general purpose I/O ports are setup.

Listing 5-1, Note 5: The Joystick I/O is initialized.

Listing 5-1, Note 6 The ADC used for the Accelerometer/potentiometer is initialized..

Listing 5-1, Note 7: The interrupt controller is initialized, including the disabling of all interrupts and the assignment of a dummy ISR handler to each interrupt vector to catch spurious interrupts.

Listing 5-1, Note 8: The I^2C interface used for the PCA9532 (which controls the LEDs and push buttons) is initialized.

Listing 5-1, Note 9: The **μC/OS-II** tick interrupt source is initialized.

Listings 5-2 and 5-3 give the **μC/OS-II** timer tick initialization function, `BSP_Tmr_TickInit()`, the tick ISR handler, `BSP_Tmr_TickISR_Handler()`. These may serve as examples for initializing an interrupt and servicing that interrupt.

```
static  void  BSP_Tmr_TickInit (void)
{
    CPU_INT32U  pclk_freq;
    CPU_INT32U  rld_cnts;


    VICIntSelect       &= ~(1 << VIC_TIMER0);                    /* Note 1 */
    VICVectAddr4        =  (CPU_INT32U)BSP_Tmr_TickISR_Handler;
    VICIntEnable        =  (1 << VIC_TIMER0);

    pclk_freq           =   BSP_CPU_PclkFreq(BSP_PCLK_TIMER0);    /* Note 2 */

    rld cnts            =   pclk freq / OS TICKS PER SEC;

    T0TCR               =  (1 << 1);
    T0TCR               =   0;
    T0PC                =   0;

    T0MR0               =   rld_cnts;                             /* Note 3 */
    T0MCR               =   3;

    T0CCR               =   0;
    T0EMR               =   0;
    T0TCR               =   1;                                    /* Note 4 */
}
```

Listing 5-2, `Tmr_TickInit()`

Listing 5-2, Note 1: The timer interrupt vector is set and the interrupt is enabled.

Listing 5-2, Note 2: The peripheral clock frequency is calculated, and this clock frequency and desired tick rate—`OS_TICKS_PER_SEC`—are used to determine the number of clocks between interrupts.

Listing 5-2, Note 3: The timer is setup to generate a periodic interrupt and then reset to zero.

Listing 5-2, Note 4: The timer is started.

```
void  BSP Tmr TickISR Handler (void)
{
    T0IR        = 0xFF;                                          /* Note 1 */

    OSTimeTick();                                                /* Note 2 */
}
```

Listing 5-3, `BSP_Tmr_TickISR_Handler()`

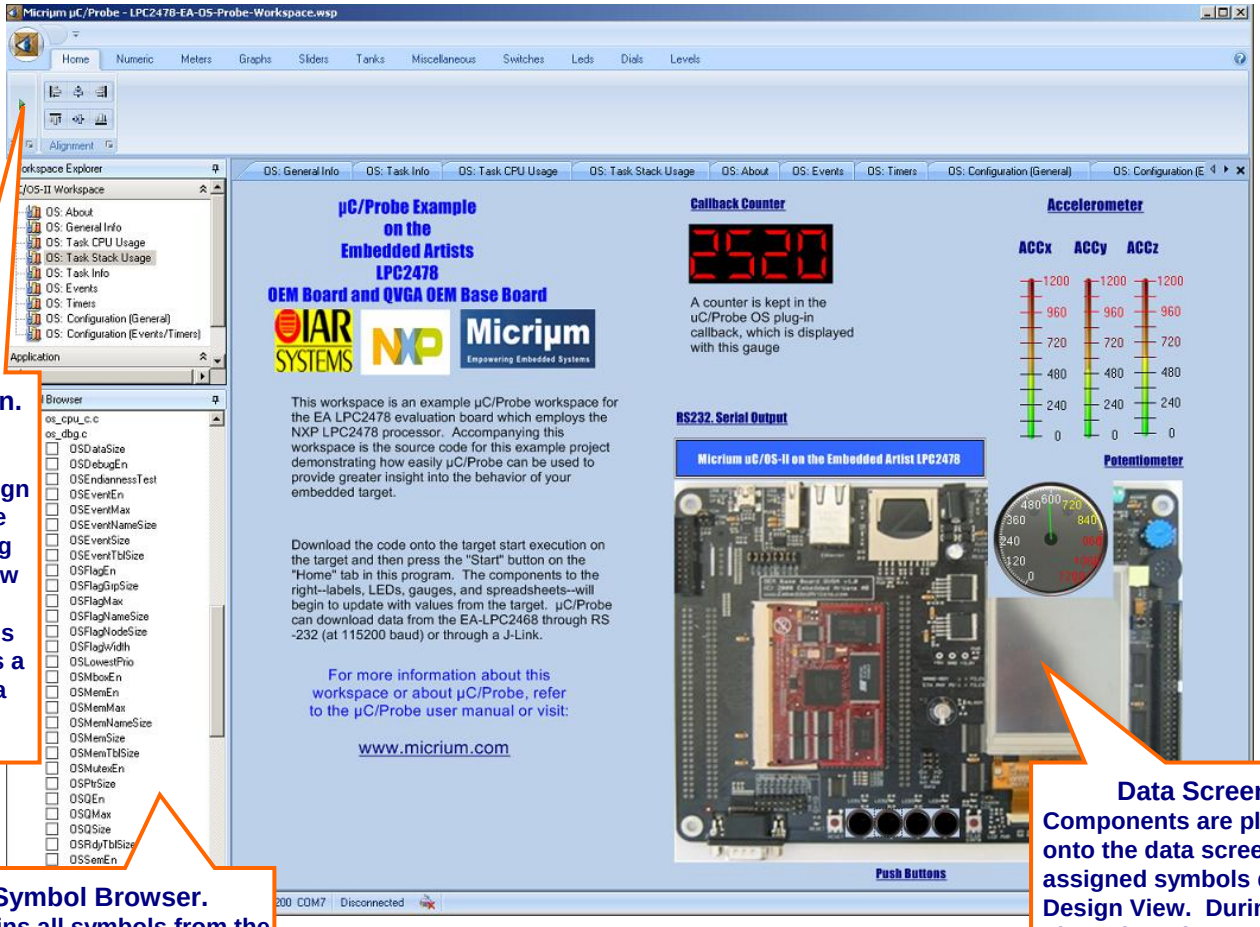
Listing 5-3, Note 1: The interrupt is cleared.

Listing 5-3, Note 2: `OSTimeTick()` informs **μC/OS-II** of the tick interrupt.

6. μC/Probe

μC/Probe is a Windows program which retrieves the values of global variables from a connected embedded target and displays the values in a engineer-friendly format. To accomplish this, an ELF file, created by the user's compiler and containing the names and addresses of all the global symbols on the target, is monitored by **μC/Probe**. The user places components (such as gauges, labels, and charts) into a Data Screen in a **μC/Probe** workspace and assigns each one of these a variable from the Symbol Browser, which lists all symbols from the ELF file. The symbols associated with components placed on an open Data Screen will be updated after the user presses the start button (assuming the user's PC is connected to the target).

A small section of code resident on the target receives commands from the Windows application and responds to those commands. The commands ask for a certain number of bytes located at a certain address, for example, "Send 16 bytes beginning at 0x0040102C". The Windows application, upon receiving the response, updates the appropriate component(s) on the screens with the new values.


Micriμm μC/Probe - LPC2478-EA-OS-Probe-Workspace.wsp
Home
Numeric
Meters
Graphs
Sliders
Tanks
Miscellaneous
Switches
Leds
Dials
Levels
OS: General Info
OS: Task Info
OS: Task CPU Usage
OS: Task Stack Usage
OS: About
OS: Events
OS: Timers
OS: Configuration (General)
μC/Probe Example on the Embedded Artists LPC2478 OEM Board and QVGA OEM Base Board
Callback Counter
A counter is kept in the uC/Probe OS plug-in callback, which is displayed with this gauge
Accelerometer
ACCx
ACCy
ACCz
This workspace is an example μC/Probe workspace for the EA LPC2478 evaluation board which employs the NXP LPC2478 processor. Accompanying this workspace is the source code for this example project demonstrating how easily μC/Probe can be used to provide greater insight into the behavior of your embedded target.
RS232. Serial Output
Micrium uC/OS-II on the Embedded Artist LPC2478
Potentiometer
Download the code onto the target start execution on the target and then press the "Start" button on the "Home" tab in this program. The components to the right--labels, LEDs, gauges, and spreadsheets--will begin to update with values from the target. μC/Probe can download data from the EA-LPC2468 through RS -232 (at 115200 baud) or through a J-Link.
For more information about this workspace or about μC/Probe, refer to the μC/Probe user manual or visit:
www.micrium.com
Push Buttons
Disconnected

Start Button. This button switches between Design and Run-Time Views. During Run-Time View (when data is collected), this will appear as a stop button (a blue square).

Symbol Browser. Contains all symbols from the ELF files added to the workspace.

Data Screen. Components are placed onto the data screen and assigned symbols during Design View. During Run-Time View, these components are updated with values of those symbols from the target

Figure 6-1. μC/Probe Windows Program

To use **μC/Probe** with the example project (or your application), do the following:

1. **Download and Install μC/Probe.** A trial version of **μC/Probe** can be downloaded from the Micriμm website at

   http://www.micrium.com/products/probe/probe.html

1. **Open μC/Probe**. After downloading and installing this program, open the example **μC/Probe** workspace for **μC/OS-II**, named ***OS-Probe-Workspace.wsp***, which should be located in your installation directory at

   /Program Files//Micrium/uC-Probe/Target/Plugins/uCOS-II/Workspace

2. **Connect Target to PC**. Currently, **μC/Probe** can use RS-232 to retrieve information from the target. You should connect a RS-232 cable between your target and computer.

3. **Load Your ELF File**. The example projects included with this application note are already configured to output an ELF file. (If you are using your own project, please refer to Appendix A of the **μC/Probe** user manual for directions for generating an ELF file with your compiler.) This file should be in

   /<Project Directory>/<Configuration Name>/exe/

   where <***Project Directory***> is the directory in which the IAR EWARM project is located (extension *.ewp) and <***Configuration Name***> is the name of the configuration in that project which was built to generate the ELF file and which will be loaded onto the target. The ELF file will be named

   <***Project Name***>***.elf***

   in EWARM v4.4x and

   <***Project Name***>***.out***

   in EWARM v5.xx unless you specify otherwise. To load this ELF file, right-click on the symbol browser and choose “Add Symbols”.

4. **Configure the RS-232 Options**. In **μC/Probe**, choose the “Options” menu item on the “Tools” menu. A dialog box as shown in Figure 6-2 (left) should appear. Choose the “RS-232” radio button. Next, select the “RS-232” item in the options tree, and choose the appropriate COM port and baud rate. The baud rate for the projects accompanying this appnote is 115200.
5. **Start Running**. You should now be ready to run **μC/Probe**. Just press the run button ( ) to see the variables in the open data screens update. Figure 6-3 displays the **μC/OS-II** workspace which displays detailed information about each task’s state.

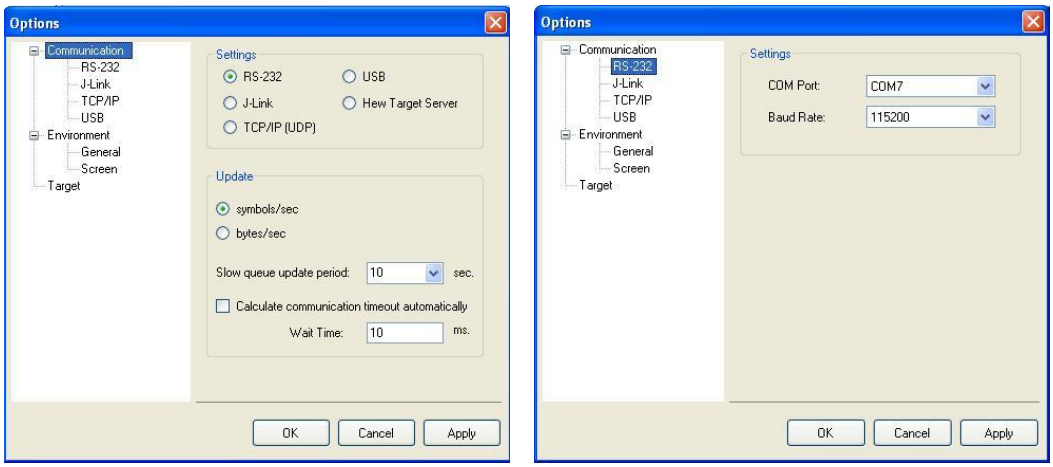


Figure 6.2. μC/Probe Options

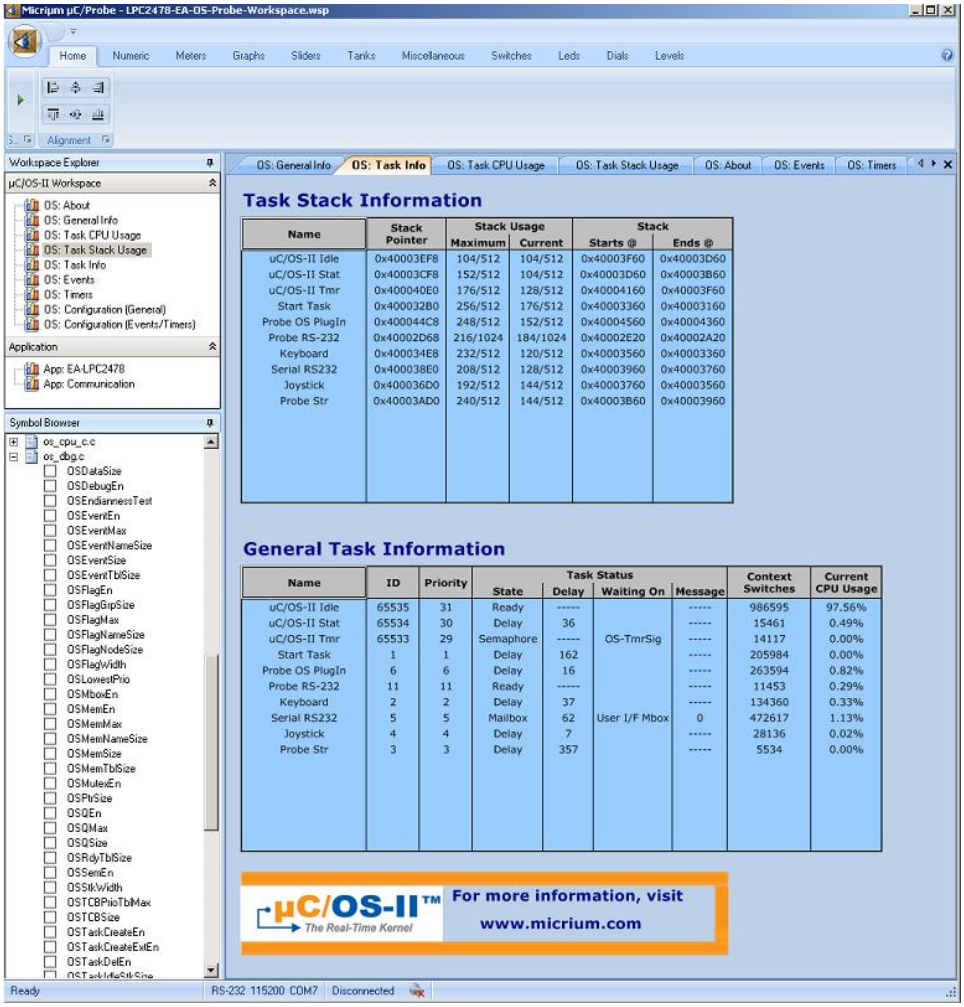


Figure 6-3. μC/Probe Run-Time: μC/OS-II Task Information

Licensing

µC/OS-II is provided in source form for **FREE** evaluation, for educational use or for peaceful research. If you plan on using **µC/OS-II** in a commercial product you need to contact Micriμm to properly license its use in your product. We provide **ALL** the source code with this application note for your convenience and to help you experience **µC/OS-II**. The fact that the source is provided does **NOT** mean that you can use it without paying a licensing fee. Please help us continue to provide the Embedded community with the finest software available. Your honesty is greatly appreciated.

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Contacts

IAR Systems
Century Plaza
1065 E. Hillsdale Blvd
Foster City, CA 94404
USA

+1 650 287 4250
+1 650 287 4253 (FAX)

e-mail: Info@IAR.com
WEB : www.IAR.com

CMP Books, Inc.
1601 W. 23rd St., Suite 200
Lawrence, KS 66046-9950
USA

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WEB : http://www.cmpbooks.com

Micriμm
949 Crestview Circle
Weston, FL 33327
USA

+1 954 217 2036
+1 954 217 2037 (FAX)

e-mail: Jean.Labrosse@Micrium.com
WEB : www.Micrium.com

NXP
1110 Ringwood Court
San Jose, CA 95131
USA

+1 408 474 8142

WEB : www.nxp.com